

Factors influencing transaction costs of prefabricated housing projects in China: developers' perspective

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Abstract

Purpose – The recent promotion of prefabricated housing (PH) in China has resulted in a prosperous period for its implementation. However, transaction costs (TCs) cause low economic efficiency to stakeholders and hinder the further promotion of PH. No relevant study has yet been made to investigate the TCs and their causes in the PH field. This paper identifies critical TCs and explores the influencing factors from the developers' perspective.

Design/methodology/approach – Semi-structured interviews and a questionnaire survey were used to collect data about TCs and influencing factors. The most influential factors are identified with their impacts on particular TCs, yielded from correlation analysis and logistic regression.

Findings – From the developers' perspective in China's PH market, this study identified that the most concerning sources of TCs are: hidden costs arising from disputes, extra workloads from design changes, learning costs, intensive communication and coordination in assembly and unexpected information costs in decision-making. The use of an ordered logistic regression approach indicates that the four most influential factors are: qualification of the general contractor, mandatory local policies, owner type and competitiveness of the developer.

Practical implications – To reduce the TCs, experiencing learning and ensuring the design scheme's complicity are recommended to save information searching and exchanging costs. The implications for the PH developers are for them to: (1) professionalize their own organization and (2) procure high-qualified general contractors. For the policymakers, this means they should improve the clarity of the mandatory local policies for PH step-by-step.

Originality/value – By applying the TCs economic theory, this study explores factors that influence TCs in the PH industry. It sheds light on the influencing mechanism behind the TCs in the context of prefabricated housing.

Keywords Transaction cost, Prefabricated housing, Developers, Stakeholders, Ordered logistic regression

Paper type Research paper

1. Introduction

Prefabrication has entailed considerable benefits to the construction industry, such as enhanced quality, shorter construction period, decreased materials cost and improved onsite working environment (Arif and Egbu, 2010). The house building sector can benefit greatly (Arashpour *et al.*, 2015). Typically, prefabricated housing (PH) projects include manufacturing components/modular in a factory, transporting and completing assembly

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onsite (Tam *et al.*, 2007). In China, where the housing sector has always been an essential part of the economy, the government has introduced stringent measures to facilitate PH (Ji *et al.*, 2017). In 2016, the authority announced that at least 30% of new construction has to adopt prefabrication by 2026 (GOSC, 2016). Under the leadership of the central government, more than 30 provinces have approved related policies and supportive measures to reach the goal. A total of 152 PH supporting policies were announced in 57 prefecture-level cities by August 2017 (Wang *et al.*, 2019). For example, the Henan provincial government would subsidize 50 RMB/m² for qualified PH projects (prefabrication rate > 30% or assembly rate > 50%) by 2025. Generally, the market size of the PH projects accounted for 13.4% of the new-built buildings in 2019, which is, however, still far less than that in the developed countries (STIDC, 2020). The unique features of China's construction have formed a widely used mechanism for projects' development. Yet, the adoption of prefabrication technologies is considered as adding risks to well-established practice (Luo *et al.*, 2015). Therefore, the smooth transition from a labor-intensive onsite method to a highly integrated prefabrication method requires the China construction industry to overcome this lock-in effect (Gan *et al.*, 2019). Numerous challenges need to be understood to succeed in PH, such as dealing with the lack of knowledge and expertise (Mao *et al.*, 2015), higher capital costs (Xue *et al.*, 2018a), new technologies (Wu *et al.*, 2019a), low process efficiency (Zhai *et al.*, 2014) and so forth. The costs spending on overcoming these challenges stemming from the attributes of the transactions in terms of asset specificity, frequency and uncertainty are mostly transaction costs (TCs) Williamson (1985). In the PH industry, TCs are defined explicitly as costs in terms of risks, time delay, information search, negotiation, contracting, organization set-up, monitoring and enforcement (Wu *et al.*, 2019b).

Common sense dictates that TCs bring both burdens and losses to the stakeholders, especially private stakeholders, because they are profit-pursuers. TCs account for quite a percentage of cost and shrink their profits (Whittington, 2008). For instance, TCs of energy-efficient buildings have been estimated to be as high as 20% of the investment cost (Gooding and Gul, 2016). In the cases where the public organization plays a developer's role, TCs are also an extra burden to them. However, they are less profit-motivated, therefore make fewer complaints about TCs compared to the private stakeholders. In the PH industry, TCs are usually unidentified or unrealized by the private enterprises. For example, additional efforts are consumed by the developers for seeking the experienced engineers and designers in PH projects (Larsson and Simonsson, 2012). The contractors complain about the rising cost from miscellaneous works such as hiring highly-skilled workers and components transportation (Hong *et al.*, 2018). The architects need to coordinate intensively for components manufacturing and assembly (Tam *et al.*, 2015). These obscure TCs limit stakeholders' production efficiency and hamper the progression of the whole industry (Qian *et al.*, 2015). To make projects more financially attractive and to smooth the PH promotion process, TCs for private stakeholders must be well understood and minimized.

The core for effectively controlling the TCs for private stakeholders is to uncover the influencing mechanism behind them. A body of research efforts has already been able to identify the factors that influence the TCs. McCann (2013) categorized and analyzed factors affecting TCs for improving environmental policy design. Coggan *et al.* (2013) built a framework for identifying factors influencing TCs for policy instruments. Phan *et al.* (2017) identified the key drivers of TCs in forestry carbon projects. Shahab *et al.* (2019) focused on what determines the amount of TCs in transferable development rights programs and how these specific effects worked. To our knowledge, the investigation of TCs is still quite a new topic in the PH industry. In particular, the factors that influence the TCs of PH are unclear and have not been studied.

This study investigates the influencing factors of TCs for private stakeholders, particularly from the developer's perspective. In the PH industry, the developer is recognized as one of the most influential stakeholders in China's context (Wu *et al.*, 2019b).

By taking the role of the clients in most PH cases, developers are participating in many transactions and bearing a large part of TCs in the project development process. The added burden from TCs has harmed developer enthusiasm to enter the market (Jiang *et al.*, 2019). Being motivated by the fact that the frictions in PH projects cannot be released without comprehensive knowledge about TCs, the study aims to seek insights into TCs and the influencing factors. It is expected to give a better understanding and control of TCs in the PH. The following questions are answered in this paper:

- (1) What are the TCs of most concern in PH from the perspective of the developers?
- (2) What are the influencing factors of developer-related TCs in PH?
- (3) How do the influencing factors influence their correlated TCs?

The findings from this study can benefit both academia and industrial practitioners through a better understanding of the TCs and production efficiency of PH. They provide insights into the private stakeholders' perceptions when identifying the ignored TCs and lay a foundation for further studies into the occurring mechanisms behind TCs.

2. Literature review

2.1 Transaction costs of PH projects in China

Prefabrication was introduced to China in the 1950s to meet the massive housing demand (Wu *et al.*, 2019a). Recently, driven by the global trend in sustainable development, PH has been a broadly advancing sustainable method in China's market. China's authorities define prefabricated housing as: "Residential buildings that are assembled onsite using prefabricated components" (MOHURD, 2018). The transformation of the construction industry from conventional methods to prefabrication is facing significant challenges in China. The new network, new cooperation, risks, mismatching between the existing governance system and the new PH supply chain are all causing extra effort, time and costs, and through this, higher TCs (Wu *et al.*, 2019b; Zhai *et al.*, 2014).

TCs generally refer to costs of transactions beyond the materials cost of the product, including the costs of searching for information, communication between stakeholders, negotiation, monitoring and dealing with deviations from contracts (Antinori and Sathaye, 2007). With a contribution to analyze and optimize the governance organization, TCs have gained considerable importance in research into the fields of project procurement (Carbonara *et al.*, 2016), new technology implementation (Kiss, 2016), policy management (Shahab *et al.*, 2018), regulation improvement (Qian *et al.*, 2016) and institutional governance (Lai and Tang, 2016). However, the concept of TCs is not universally accepted by all practitioners in the construction industry (Li *et al.*, 2014b). Knowledge and evidence of TCs are still limited in the field of PH. In this study, TCs in the PH industry are defined explicitly as costs in terms of risks, time delay, information search, negotiation, contracting, organization set-up, monitoring and enforcement (Wu *et al.*, 2019b).

TCs are unique in a particular transaction environment. It is hard to give a justification for the level of TCs between PH and traditional projects. Two arguments can be made for investigating them:-

- (1) Some of the TCs in PH are commonly seen in conventional construction projects; however, the content and scale of these TCs are different compared with the traditional projects. For example, TCs for the feasibility study of PH projects are different from conventional projects due to the extra performance of prefabrication on the aspects of technical, economic and social influence (Antinori and Sathaye, 2007). Besides, the detailed design of PH projects contains further TCs on components

- design, for example, more negotiation to ensure the transporting (Mundaca, 2007), lifting and incorporating of different components together (O'Connor *et al.*, 2015).
- (2) Apart from the commonly seen TCs in conventional construction projects, there are some TCs specific for PH projects, including identifying partners with PH experience (Kiss, 2016), establishing the technical scheme, hiring skilled labor and tests on components quality (Mundaca, 2007). For conducting the prefabrication construction, local laborers' extra training to get machine-oriented skills needs to be accomplished (Chiang *et al.*, 2006). Components transportation is a new task that connects the offsite manufacturing and the onsite assembly, which is identified as a vital challenge that needs intensive coordination (Kamali and Hewage, 2016). It can be derived from the literature that TCs in the current China PH market are higher than expected. TCs are perceived to be too high due to the uncertainties from adopting the renovation technologies and production process (Winch, 1989). In this sense, there is considerable potential for TCs in China's PH to be reduced (Wu *et al.*, 2019b),

2.2 Developer-related TCs in PH

Stakeholders involved in the PH project should realize the existence and importance of TCs. In the context of China, the developers are generally acknowledged as taking the leading role in promoting PH (Xue *et al.*, 2018b); hence the developers' perspective is a valuable view to take. In the typical PH projects, developers initiate and organize the whole development process; therefore having more contractual relationships and information exchanges. Through taking the role of the clients in most PH cases, developers are participating in many transactions and bearing more TCs than other stakeholders in PH projects (Wu *et al.*, 2020). Therefore, for exploring the TCs in PH, the first step is to overview TCs from the developers' perspective. Considering the limited research about TCs of developers in the PH field, TCs related to developers are identified by reviewing the literature about barriers in the PH, TCs in the construction industry and the application of TCs theory in other fields. Table 1 has concluded the developers-related TCs in the development process of PH projects.

Taking the role of initiator in many PH projects, most of the developers' TCs arise at the early stage of the projects' development process. Apart from the similar TCs from project brief and feasibility study in conventional projects, efforts on looking for potentials partners with PH Experience (TC₃) are identified as a significant source of TCs. Larsson and Simonsson (2012) stated the challenge of the lack of knowledgeable professionals for PH, especially experienced architects and engineers. Besides, learning activities (TC₅), such as digesting new information, mastering new technologies and adapting the organization to the prefabrication mode, can lead to additional costs (Wu *et al.*, 2019b). For the decision-making in PH projects (TC₆), the long lead-in time, more work from information collection and analysis are also recognized as hindrances (Goodier and Gibb, 2007). In the plan and design phase, developers are responsible for TCs such as Land-bidding (TC₇), Permission Application (TC₈), General Contractor Procurement (TC₁₃), etc. (Wu *et al.*, 2019b). Notably, the Detailed Design (TC₁₂) in a PH project would typically consume a longer time of professionals taking the feasibility of assembly into account (O'Connor *et al.*, 2015). TCs related to the developers also appear in the construction phase, arising from the Design Changes (TC₁₅) (Tam *et al.*, 2015) and Disputes (TC₁₆) (Lu *et al.*, 2015). Furthermore, to ensure the efficiency of implementing the construction contracts, enforcement measures, such as construction monitoring and quality inspection for the assembly, are also taken from the developers' side (Rajeh *et al.*, 2015). In the operation phase, as the client and owner in many cases in China, developers are responsible for TCs from Advertising (TC₁₈) (Wu *et al.*, 2019b), Contract Signing (TC₁₉) (Mundaca, 2007) and Taxation (TC₂₀) (Xue *et al.*, 2018b).

Table 1.
Sources of developer's
transaction costs (TCs)

	Code	Sources of TCs
Conceptual phase	TC ₁	Preparation of a project brief
	TC ₂	Evaluating the project's feasibility
	TC ₃	Identifying experienced partners
	TC ₄	Consultation about prefabrication in the conceptual and design phase
	TC ₅	Learning new technologies, digesting new information and adapting the organization to the prefabrication mode
	TC ₆	Decision-making for adopting prefabrication technologies and the prefabrication rate
	TC ₇	Preparing and participating in the land-bidding
	TC ₈	Obtaining approvals and permits in the conceptual and design phases
	TC ₉	Preparing and negotiating for the financing
	TC ₁₀	Land-surveying
	TC ₁₁	Information searching, learning and communication for architectural design
	TC ₁₂	Information collection, communication and coordination to complete the detailed design
Construction phase	TC ₁₃	Procuring the general contractor
	TC ₁₄	Setting up the project organization
	TC ₁₅	Communication, negotiation, time delay and rework from the design change
	TC ₁₆	Dispute costs
	TC ₁₇	Communication, monitoring and quality inspection for the assembly
Operation phase	TC ₁₈	Advertising, popularization and promotion of PH projects
	TC ₁₉	Drafting, negotiating and signing the sale contracts
	TC ₂₀	Taxation paid by the developer in the project development process

2.3 Factors that influence TCs in PH

Williamson (1996) defines the determinants of TCs as specificity, uncertainty, frequency, bounded rationality and opportunism. Mettepenningen *et al.* (2011) classify the determinants of TCs into factors relating to the actors, characteristics of the schemes, institutional environment and natural environment. McCann (2013) classifies factors affecting TCs into physical, cultural and institutional environment factors for improving environmental policy design. Coggan *et al.* (2013) also develop a framework for identifying factors influencing TCs for environmental policy instruments based on characteristics of the transaction, characteristics of the transactors, the nature of the institutional environment and the nature of the institutional arrangements. In the Chinese construction industry, factors affecting TCs are categorized into the predictability of the owner's behavior, predictability of the contractor's behavior, project management efficiency and uncertainties in the environment (Li *et al.*, 2012).

Based on previous studies, this study developed a framework as a basis for identifying the factors influencing TCs in PH, as outlined in Table 2. We argue that the factors that influence TCs in the PH industry are comprised of three categories:

- (1) *The attributes of transactions*: the asset specificity of the transacted items, the frequency of the transaction and the level of uncertainties in the transaction process;
- (2) *The characteristics of stakeholders*: factors regarding bounded rationality, opportunism and information asymmetry;
- (3) *The institutional environment*: the context where the economic activities take place, with its particular features of formal and informal legal, social and political rules.

2.3.1 *The attributes of transactions*. Conforming to Williamson (1985), the characteristics of a transaction can be defined concerning its asset specificity, uncertainty and frequency.

Categories	Factors	Explanation	References
Attributes of transactions	Project Location	Location and scale are the project factors that impact TCs	Phan <i>et al.</i> (2017)
	Project Size	Larger projects require more effort in monitoring, which increases TCs	Torres and Pina (2001)
	Owner Type	The owner type largely determines the pre- and post-contract TCs	Li <i>et al.</i> (2014a, b)
	Prefabrication Rate	High technical complexity raises uncertainties in the transaction process, hence increasing the cost of procurement and execution	Farajian (2010), Li <i>et al.</i> (2012)
	Procurement Method	Fragmented design and construction is typical in the design-bid-build procurement system and contributes to the uncertainties, hence increasing TCs	Li <i>et al.</i> (2014a, b), Rajeh <i>et al.</i> (2015)
	Contract Type	The contract type of projects determines the frequency of the payment and therefore has a direct impact on TCs	Chen <i>et al.</i> (2013), Li <i>et al.</i> (2014a, b)
Characteristics of Stakeholders	Collaboration Experience	The interaction among partners necessitates communication and governance and familiarity improves transactions	De Schepper <i>et al.</i> (2015)
	Experience	Lessons learned from previous experience can be applied in future projects and stability in the owner's behavior greatly reduces TCs	Mettepenningen <i>et al.</i> (2011)
	Qualification of the General Contractor	Contractors with outstanding operation capability help build an efficient transaction environment and stability lowers TCs	Li <i>et al.</i> (2014a, b)
Institutional environment	Social Climate and Attitudes	When systems work well, people do not like change. Once people have adapted to an institutional structure, changing will be quite costly	Mettepenningen <i>et al.</i> (2011)
	Local Policies	Policies impact TCs by directing how the exchanges take place	Wu <i>et al.</i> (2019b)

Table 2. Factors that influence the TCs of PH projects

Accordingly, the attributes of the transaction in PH that affect the TCs can be summarized, including the project location, project size, owner type, prefabrication rate, procurement method and contract type.

The location of projects in different regions can influence the TCs because the development of PH between cities is different. According to the market situation of different cities, China central government set particular goals for PH promotion by categorizing cities into three types: The newly-built prefabricated buildings are expected to reach 20% of total construction for the primary promotion region, 15% for the positive promotion region and 10% for the encouraging promotion region (GOSC, 2016; MOHURD, 2018). Besides, plenty of studies have shown that the size of construction projects has a significant influence on the scale of TCs (Torres and Pina, 2001). Ho and Tsui (2009) assert that the project scale and project complexity will primarily affect contracting costs. Similarly, Carbonara *et al.* (2016) found that TCs increase when the project size grows due to a more considerable effort to monitor and negotiate. Additionally, the owner type of project is an essential determinant of

TCs. The owner type indicates the type of ownership (public or private) of PH buildings. The owner type determines the developers' decision-making flexibility in pre-contract management, determining access to alternative dispute resolutions (Li *et al.*, 2014b).

The prefabrication rate reflects the technical uncertainties in a PH project, which is believed as an essential factor of TCs (Farajian, 2010). The target prefabrication rate of the project defines the technical complexity of the projects. It can be connected to Williamson's argument of asset specificity, which positively correlates with TCs (Shahab *et al.*, 2018). The higher the prefabrication rate, the more challenges arise in techniques, workers' training, cooperation, communication, etc.

The procurement method and contract type of a PH project determine the frequency of transactions in its development process. Particular procedures and routines tailored to a particular transaction (Coggan *et al.*, 2013), the procurement method is, therefore, a vital effect factor of TCs in a project's development. TCs related to the different procurement situations vary on the volume of information to be processed. The higher the specificity (i.e. uniqueness and uncertainty) of the procurement, the more need to exchange and share fresh information (Carbonara *et al.*, 2016). Besides, the effect of contract type on TCs is a typical reflection of the influence of transaction frequency. The main construction contract is a single transaction and can be viewed as a series of transactions, implying high transaction frequency (Chen *et al.*, 2013). The contract type of PH projects, including Lump-sum, Unit-price, Cost-plus-fee, etc., determines the payment frequency and, therefore, directly impacts TCs.

2.3.2 The characteristics of the stakeholders. The characteristics of the stakeholders are identified according to the concept of information asymmetry, bounded rationality and opportunism. Factors in this category include collaboration experience, experience on PH and the qualification of contractors.

The theory of information asymmetry and knowledge specificity all pointed out that previous collaboration experience within a group of stakeholders is a critical influencing factor of TCs (Jobin, 2008). Particular skills, knowledge and expertise of staff are specific to a transaction. The challenges of communication, negotiation, coordination and governance could be better addressed if stakeholders have had previous dealings with each other (Coggan *et al.*, 2013).

Bounded rationality acknowledges that rational people's decision and behavior are bounded by the information available, time, cognition and ability to foresee all contingencies (Simon, 1950). Experience learning is valid if the lessons learned from completed projects are kept in the organizational memory and used in future projects. The more experience the actor has, the lower TCs will be, indicating a learning effect (Mettepenningen *et al.*, 2011).

TCs occur from developing complete contracts and monitoring to manage risks from opportunistic behaviors. Trust and confidence in the stakeholders' information flow can reduce TCs associated with opportunism (Li *et al.*, 2014b). Contractors with a high level of qualification, meaning relatively strong capability, provide the basis for building trust and stability in cooperation. In China, the qualification of housing construction general contractors is divided into four levels: special grade, first level, second level and third level. According to the Standard of qualification for construction enterprises in China's construction industry, the special grade is the top level of the construction contractors (MOHURD, 2014). The higher level of enterprises' qualification represents the high capability of creditworthiness, management capability and experience. For instance, the requirements about the registered capital for four levels of certification are above 300 million CNY, 50 million CNY, 20 million CNY and 6 million CNY (from special grade to the third level), respectively. Additionally, for the special grade certification, there are additional requirements for scientific progress.

2.3.3 The institutional environment. The institutional environment has a significant influence on the TCs, ranging from political settings such as legal regulations and

organizations to social climate and attitudes (Coggan *et al.*, 2013). The factors, namely the social environment and the policies, are summarized here from the literature with evidence showing their impacts on the TCs.

Social climate and public attitudes are identified as relevant TCs influencing factors for agri-environmental schemes by Mettepenningen *et al.* (2011). It is claimed that significant changes to the technology and the management system are unlikely to be encouraged in a short time because of path dependency. PH is leading the upgrading of the construction industry, while public knowledge and attitude toward PH are of considerable significance to the advancement of construction transformation (Wang *et al.*, 2019).

Policies impact TCs through directing how exchange takes place, which, in turn, imposes influence on TCs to both public and private parties (Coggan *et al.*, 2013). For instance, policy design and briefing generate TCs to the public stakeholders, while the private stakeholders are also bearing TCs from learning and adapting to the policy. The government could influence the application of new technology by policies, for example, tax incentives (Wu *et al.*, 2019a). Thus, a market with supportive policies can lower the information-searching costs for private stakeholders.

3. Methodology

The methodology of this study consisted of four steps, as presented in Figure 1. The first step was to perform the qualitative research, namely, semi-structured interviews, to improve the list of factors identified by an extensive literature review. We followed this with a quantitative method, namely a questionnaire survey, to elicit the states of the factors and evaluate the importance of the TCs. The third and fourth steps are data analysis to identify the influencing factors of TCs, using the methods of correlation analysis and ordered logistic regression. Details of the semi-structured interviews and the questionnaire survey are described in the following subsections.

3.1 Semi-structured interviews

The semi-structured interviews were designed to validate the accuracy and completeness of the theoretical factors. To get in touch with experts with a wealth of experience in PH, we visited the Prefabricated Building and Construction Technology Expo, 22–24 November 2018, in Changsha, China. Ten experts participating in the Expo agreed to participate in our research. All of the interviews were conducted on a face-to-face basis in the location of the Expo. Each interview lasted for around 30 min. The selected interviewees are from the developer and include professionals from the government, construction companies,

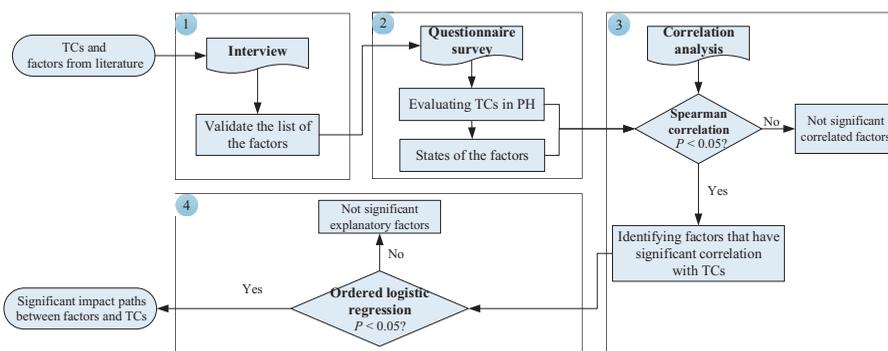


Figure 1. Methodology design

consultants, component suppliers and architects. Profiles of the ten interviewees can be seen in [Table 3](#).

During the interview, the interviewees were asked: (1) to verify and adjust the list of factors that influence TCs in PH projects from their perspectives, (2) to share more views about the causes of TCs beyond the framework and (3) to explain how each factor influence TCs of developer based on their experience in PH. Note-taking and recording were done by the agreement of the interviewees. Then, a code-based content analysis was carried out, which helped to organize data in the identified factors to enable the analysis and interpretations. The authors also reviewed related policy documents, reports and literature to provide theoretical supports for the experts' input.

As suggested by the interviewees, the factor – *Social climate and attitude* – has been removed from the list. Feedback from the participants said that it was not easily-understandable for them to evaluate an item with many explanatory variables behind each. The social attitude includes the attitudes of the authorities, co-operators, workers and the end-users, all of which are quite complex and cannot be qualified by using one variable.

The *Competitiveness of the developer* has been added, as suggested by the interviewed experts. The rank of a developer in the Top 100 Chinese real estate enterprises is a direct reflection of its competitiveness. This annually released official list indicates the competitiveness of the developers based on 52 business indices, such as profitability, solvency, sustainable development and operational capacity. [Haan et al. \(2002\)](#) claimed that the developers' competitiveness mirrors their capability to respond to the changes and risks in the environment where most TCs incur promptly. In China's housing developing market, the developers with different competitiveness have different sources to guarantee production. Compared with small enterprises, competitive real estate developers naturally have advantages in learning new technologies, identifying partners, financing, etc. ([Statista, 2020](#)).

The policy environment has been divided into two factors: *Mandatory local policy* and *Local incentives*. The interviewees believed that mandatory local policies have an essential influence on PH in the Chinese market. For example, when the government of Tianjin city announced that five types of projects must adopt prefabrication from 2018, the local real estate developers had to raise their investment to meet the increasing demands on technical supports, skilled labor and upgrading management system for PH. It can be explained that adapting to new regulations and facing risks in new production activities generate unexpected costs ([Qian et al., 2013](#)) because mandatory policies change the rules or the consequence of the new norm. Considering the different policy environments in different

Code	Role of the company	Position	Experience in PH (year)
1	General contractor	Technology director	6
2	Developer + General contractor	Marketing manager	1.5
3	General contractor + component supplier + Consultant	Marketing manager	3
4	Consultant + General contractor	Architect	2.5
5	Developer + General contractor + consultant	Deputy general manager	7
6	General contractor + component supplier	Architect	3
7	General contractor + component supplier	Architect	2
8	Architects	Senior engineer	4.5
9	Developer	Head engineer	4
10	Local government	Director	6.5

Table 3.
Profiles of the
interviewees

regions in China, the local compulsory policy's status has been defined at three levels: (1) No mandatory requirements; (2) Must use prefabrication; (3) Has a specific requirement on the prefabrication rate. As for the incentive policies, they have been published mainly in three types according to the research of Jiang *et al.* (2019): (1) Only non-economic incentives: Including reputation incentives (e.g. qualification promotion, priority awards), pre-sale policy, priority in the approval, traffic support; (2) Only economic incentives: including fund support, loan support, tax privilege, floor area reward and priority land supply; (3) Combination of economic and non-economic incentives.

After the validation by the semi-structured interviews, a full list of factors potentially affecting developer-related TCs for PH projects was identified (Table 4).

3.2 Questionnaire survey

Based on the validated factors list, a questionnaire survey was conducted. The obtained information about TCs and the states of factors provides evidence on how the TCs are influenced in PH projects. It was a perception-based survey for developers in China, carried out from 20th December 2019 to 8th March 2020. The questionnaires were developed and distributed through an online survey platform – wj.qq.com. The questionnaire survey was conducted with the assistance of the secretary from the website – precast.com.cn. It is an organization established in 2010 by several provincial Building Industrialization Associations in China. The questionnaires were distributed to around 1,500 of their members. There were 401 responses. Respondents were asked to verify that they were currently working for PH developers before continuing to fill out the questionnaire. Consequently, 249 among 401 respondents were verified to complete the questionnaire (247 valid responses). The valid samples were collected from 31 of 34 provinces in China (no sample from Tibet, Hong Kong and Taiwan).

The first section of the questionnaire captured the respondents' background information, such as education, year of experience in construction and PH. The second section asked for information about the states of the factors (with the explanation of the states given). The third section was designed to evaluate the level of 20 sources of TCs using a five-point Likert-type scale from 1 (extremely low) to 5 (extremely high). Reliability testing was conducted for the pilot study before the final questionnaire survey. The most popular Cronbach's alpha was used, which is commonly-accepted for testing the internal consistency reliability. The Cronbach's alpha for the TCs evaluation section was 0.95 (threshold = 0.8), indicating that the questionnaire adopted has a high internal consistency (Taber, 2018).

Table 5 shows the characteristics of the samples. Overall, the majority of the respondents have either an education degree in Junior college or Bachelor's (27.94% and 60.73%). It implies that the respondents are well-educated. Having enough knowledge of the current PH market, their opinions are valuable for exploring the TCs of China's PH industry. As for the respondents' experience, it is interesting to notice that 38.06% of the respondents had longer than five-year experience in construction. In comparison, only 3.64% of the respondents had experience in PH for longer than five years. This is reasonable considering the stage of development of PH in China. A massive application of PH in China's construction market had only been started after 2010 since the publishing of a milestone policy – Plan on Green Building (MOHURD, 2013). With such a short history of implementation, it was almost impossible to find respondents with more extensive experience (e.g. >10 years) in China's PH market. Moreover, there was an open question in the first section asking for the respondents' position in their company. Fifty-three among the 247 respondents stated their positions at a manager level, such as director, section chief, department manager, technical manager, project manager or even shareholder. It indicated that the information collected by this

Factors	Description	States	
1	Project Location	38 cites in Beijing-Tianjin-Hebei Urban Agglomeration Region, Yangtze River Delta Urban Agglomeration and Pearl River Delta Urban Agglomeration 27 cities with permanent population >3 million Other cities in mainland China	Primary promotion region Positive promotion region Encouraged promotion region
2	Project Size	Floor area <100,000 m ² 100,000–200,000 m ² >200,000 m ²	Small Medium Large
3	Owner Type	Private housing: the sponsor is the developer Public housing: the owner and the sponsor is the government	Private Public
4	Prefabrication Rate(by volume)	<25% 25%–50% >50%	Low Medium High
5	Procurement Method	Design-bid-build Design-build Engineering Procurement Construction Construction Management, turnkey, partnering, etc.	DBB DB EPC Others
6	Contract Type	The type of the main construction contract	Lump-sum Unit-price Cost-plus-fee Others
7	Collaboration Experience	Have the team members worked together before, on another project, before this one?	Yes No
8	Experience of PH	How many PH projects have been developed by your company in the past 3 years?	<3 3–10 >10
9	Competitiveness of the Developer	The ranking of your current company among the Top 100 Chinese Real Estate Enterprises?	TOP 10 10–50 50–100 Not on the list
10	Qualification of the General Contractor	Construction enterprise qualification standards, 2015	Special grade First-level Second-level Third-level
11	Mandatory Local Policies	(Province level)	No Mandatory Policies Must use prefabrication Has a specific requirement on the prefabrication rate
12	Local Incentives	Including Reputation incentive, pre-sale policy, optimize the approval process, bidding policy, traffic support, etc. Including fund support, loan support, tax privilege, floor area reward, and priority land supply, etc.	No incentives Only non-economic incentives Only Economic incentives Economic + Non-economic incentives

Table 4.
Validated list of factors affecting TCs for PH projects

		Frequency	Percentage	Transaction costs of PH projects	
Educational Attainment	Junior college	69	27.94		487
	Bachelor	150	60.73		
	Master	27	10.93		
	Doctor	1	0.40		
Years in construction	0–5	153	61.94		
	5–10	67	27.13		
	10–20	20	8.10		
	>20	7	2.83		
Years in PH	<1	112	45.34	Table 5. Sample characteristics	
	1–3	97	39.27		
	3–5	29	11.74		
	5–10	5	2.02		
	>10	4	1.62		

survey was primarily based on the points of view from the managers who have an overall view of the project development process, thus being quite reliable.

4. Data analysis results

4.1 Developers' perception of TCs

The information from the first section of the questionnaire was analyzed to capture the importance ranking of TCs in the PH (Table 6). Statistical analysis was performed using IBM SPSS 25.0. The method of Mean Comparison has identified the five most important sources of TCs in PH from the opinion of the developers in China: Disputes (TC₁₆), Design Changes (TC₁₅), Learning (TC₅), Assembly (TC₁₇) and Decision-making (TC₆).

4.2 Identifying the influencing factors

The second section of the questionnaire provided information about the states of 12 factors, shown in Table 7. The data set was then subjected to multiple ordered logistic regression to identify the correlated factors for TCs and estimate the power and direction of the influences. Before the logistic regression analysis, two statistical methods were employed to guarantee that the regression assumptions are valid: (1) Collinearity test among factors (independent variables) and (2) Correlation analysis to identify the factors that statistically have a significant correlation with TCs.

First, the pre-condition before correlation analysis is to find variables statistically with non-multicollinear (for meaningful inference). In this study, variance inflation factors (VIF) were used to detect the severity of multicollinearity. A maximum VIF greater than 10 is thought to signal harmful collinearity (Marquardt, 1970). A correlation matrix was developed to see if any correlation exists among the independent variables selected from the previous procedures. As shown in Table 8, correlations among variables included in this model are low (VIF < 10), suggesting that the potential problem of multicollinearity is not severe in this study. Therefore, all these 12 factors were allowed to be included in the subsequent correlation analysis.

Second, the Spearman correlation was calculated to filter the factors that have correlations with the TCs. As the results show, in Table 9, 8 of 20 TCs have at least one factor showing a significant correlation. It means that although all these factors are theoretically useful in explaining the occurrence or the size of TCs in PH, it does not mean that all factors are significant.

Code	Sources of TCs	Mean	N	Std. Deviation
TC ₁₆	Dispute costs	3.47	247	1.096
TC ₁₅	Communication, negotiation, time delay, and rework from the design change	3.42	247	1.130
TC ₅	Learning new technologies, digesting new information, and adapting the organization to the prefabrication mode	3.38	247	1.000
TC ₁₇	Communication, monitoring, and quality inspection for the assembly	3.34	247	1.074
TC ₆	Decision-making for adopting prefabrication technologies and the prefabrication rate	3.33	247	1.033
TC ₃	Identifying experienced partners	3.29	247	1.041
TC ₉	Preparing and negotiating for the financing	3.28	247	1.090
TC ₁₃	Procuring the general contractor	3.27	247	1.110
TC ₁₂	Communication, coordination, and information collecting and adapting to complete the detailed design	3.26	247	1.097
TC ₇	Preparing and participating in the land-bidding	3.24	247	1.150
TC ₈	Obtaining approvals and permits in the conceptual and design phases	3.23	247	1.094
TC ₁₈	Advertising, popularization, and promotion of PH projects	3.20	247	1.137
TC ₄	Consultation about prefabrication in the conceptual and design phase	3.19	247	1.029
TC ₂	Evaluating the project's feasibility	3.19	247	0.988
TC ₁	Preparation of a project brief	3.15	247	1.087
TC ₁₁	Information searching, learning, and communication for architectural design	3.14	247	1.082
TC ₂₀	Taxation paid by the developer in the whole project development process	3.14	247	1.104
TC ₁₉	Drafting, negotiating, and signing the sale contracts	3.06	247	1.114
TC ₁₄	Setting up the project organization	3.02	247	1.121
TC ₁₀	Land-surveying	2.96	247	1.173

Table 6.
Rank of the importance
of TCs by developer

Third, multiple ordered logistic regression analysis was performed to judge how these eight TCs are impacted by their correlated factors.

The reasonability and the effectiveness of the ordered logistic regression models were tested. First, there is an essential assumption that parameters should not change for different categories (levels) of the dependent variable in ordered for logistic regression models. In other words, the correlation between independent variables and the dependent variable does not change for dependent variable's levels; also, parameter estimations do not change for different levels in the regression equation. The test of Parallel Lines examines whether the assumption holds or not. In this study, Parallel Lines' tests indicated that the parameters are the same for all levels of TC ($p > 0.05$), meaning that the adoption of the ordered logistic regression model is reasonable. Second, the Model Fitting test results met the statistical significance at the level of $P < 0.05$, which indicates the effective meaning of the ordered logistics regression models for each TC and correlated factors. Considering a significance level of 5%, Table 10 depicts the results from the multiple ordered logistic regression models and the odds ratios for each model considered.

- (1) The *Qualification of the General Contractor* (F10) is a significant explanatory parameter to four sources of TCs in PH: Dispute Cost (TC₁₆), Financing (TC₉), Land-bidding (TC₇) and Taxation (TC₂₀). As highlighted in Table 10, the negative coefficients for these models reveal that the higher value of the F10 is assigned to higher ratings in TCs. The ordered logistic regression analysis for TC₁₆ and its three related factors show that only F10 is the significant impact factor. The odds of general contractors with third-level qualifications (code 4) that contribute to high dispute

Factors	Code	States	Frequency	%	
F1	Project Location	1	Primary promotion region	78	31.6
		2	Positive promotion region	88	35.6
		3	Encouraged promotion region	81	32.8
F2	Project Scale	1	Small	143	57.9
		2	Medium	77	31.2
		3	Large	27	10.9
F3	Owner Type	1	Private	178	72.1
		2	Public	69	27.9
F4	Prefabrication Rate	1	Low	109	44.1
		2	Medium	111	44.9
		3	High	27	10.9
F5	Procurement Method	1	DBB	88	35.6
		2	DB	69	27.9
		3	EPC	44	17.8
		4	Others	46	18.6
F6	Contract Type	1	Lump-sum	121	49.0
		2	Unit-price	58	23.5
		3	Cost-plus-fee	43	17.4
		4	Others	25	10.1
F7	Collaboration Experience	1	Yes	180	72.9
		2	No	67	27.1
F8	Experience of PH	1	<3	107	43.3
		2	3–10	101	40.9
		3	>10	39	15.8
F9	Competitiveness of the Developer	1	TOP 10	48	19.4
		2	10–50	51	20.6
		3	50–100	46	18.6
		4	Lower than 100	102	41.3
F10	Qualification of the General Contractor	1	Special grade	74	30.0
		2	First-level	99	40.1
		3	Second-level	44	17.8
		4	Third-level	30	12.1
F11	Mandatory Local Policies	1	No Mandatory Policies	75	30.4
		2	Mandatory for adopting prefabrication	106	42.9
		3	Has a specific requirement on the prefabrication rate	66	26.7
F12	Local Incentives	1	No incentives	51	20.6
		2	Only Non-economic incentives	91	36.8
		3	Only Economic incentives	44	17.8
		4	Economic + Non-economic incentives	59	23.9

Table 7. Descriptive statistics of the factors

costs are 2.641 ($=1/0.379$) times more than the odds of special-grade general contractors (code 1). The results of analysis show that TC9 – Preparing and negotiating for the financing – can be significantly influenced by the factor F10 ($p < 0.05$). The decrease in general contractors' qualifications from the special grade to the third level will correspondingly increase the odds of higher TCs for financing at 2.591 ($=1/0.386$) times. Similarly, for Taxation (TC20), high TCs are less likely to be incurred by the special-grade general contractors (code 1), referring to the third-level qualification. Additionally, it is worth noticing that for TC7 – Preparing and participating in the land-bidding, significant differences are shown between group 4 and the other three groups. The likelihood of general contractors with third-level qualifications experiencing higher TCs is higher than that for the other groups (code 1, code 2, code 3) at 5.523, 2.762 and 2.743 times respectively.

Table 8.
Collinearity statistics
among twelve factors

Factors	Tolerance	VIF
F1	0.871	1.148
F2	0.761	1.315
F3	0.939	1.065
F4	0.730	1.369
F5	0.861	1.161
F6	0.828	1.207
F7	0.887	1.127
F8	0.867	1.153
F9	0.606	1.650
F10	0.636	1.573
F11	0.814	1.532
F12	0.858	1.166

Table 9.
Spearman correlation

Rank	Source of TCs	Correlated factors (Sig.<0.05)
TC ₁₆	Dispute costs	F4 F10 F11
TC ₁₅	Communication, negotiation, time delay, and rework from the design change	–
TC ₅	Learning new technologies, digesting new information, and adapting the organization to the prefabrication mode	–
TC ₁₇	Communication, monitoring, and quality inspection for the assembly	–
TC ₆	Decision-making for adopting prefabrication technologies and the prefabrication rate	F3
TC ₃	Identifying experienced partners	F11
TC ₉	Preparing and negotiating for the financing	F10
TC ₁₃	Procuring the general contractor	F9
TC ₁₂	Communication, coordination, and information collecting and adapting to complete the detailed design	–
TC ₇	Preparing and participating in the land-bidding	F9 F10
TC ₈	Obtaining approvals and permits in the conceptual and design phases	–
TC ₁₈	Advertising, popularization, and promotion of PH projects	–
TC ₄	Consultation about prefabrication in the conceptual and design phase	–
TC ₂	Evaluating the project's feasibility	–
TC ₁	Preparation of a project brief	–
TC ₁₁	Information searching, learning, and communication for architectural design	–
TC ₂₀	Taxation paid by the developer in the project development process	F10
TC ₁₉	Drafting, negotiating, and signing the sale contracts	F10 F11
TC ₁₄	Setting up the project organization	–
TC ₁₀	Land-surveying	–

- (2) *Owner type* (F3) of a PH project emerges as having a noteworthy influence on TCs from Decision-making (TC6). The estimated β value at -0.532 means that private PH projects (code 1) are less likely to raise higher TCs than public projects (code 2). Public projects increase the odds of higher decision-making costs at 1.730 ($=1/0.578$) times of private projects.

TCs	Correlated factors	Parameter estimate β	Std. Error	Wald	Sig.	Odds ratio exp (β)	OR 95% confidence interval	
							Lower bound	Upper bound
TC ₁₆	[F4 = 1]	0.679	0.414	2.687	0.101	1.972	0.876	4.442
	[F4 = 2]	0.515	0.396	1.687	0.194	1.673	0.770	3.637
	[F4 = 3]	0 ^a				1		
	[F10 = 1]	-0.971	0.407	5.687	0.017*	0.379	0.170	0.841
	[F10 = 2]	-0.542	0.396	1.875	0.171	0.581	0.268	1.264
	[F10 = 3]	-0.266	0.440	0.365	0.546	0.767	0.324	1.815
	[F10 = 4]	0 ^a				1		
	[F11 = 1]	0.492	0.326	2.278	0.131	1.636	0.863	3.101
	[F11 = 2]	-0.035	0.291	0.014	0.904	0.966	0.545	1.709
[F11 = 3]	0 ^a				1			
TC ₆	[F3 = 1]	-0.532	0.260	4.180	0.041*	0.587	0.352	0.978
	[F3 = 2]	0 ^a				1		
TC ₃	[F11 = 1]	0.617	0.309	3.988	0.046*	1.853	1.011	3.393
	[F11 = 2]	0.121	0.284	0.182	0.670	1.129	0.647	1.971
	[F11 = 3]	0 ^a				1		
TC ₉	[F10 = 1]	-0.951	0.395	5.792	0.016*	0.386	0.178	0.838
	[F10 = 2]	-0.483	0.378	1.636	0.201	0.617	0.294	1.293
	[F10 = 3]	-0.326	0.428	0.579	0.447	0.722	0.312	1.671
	[F10 = 4]	0 ^a				1		
TC ₁₃	[F9 = 1]	0.449	0.316	2.019	0.155	1.567	0.843	2.913
	[F9 = 2]	0.685	0.311	4.844	0.028*	1.985	1.078	3.654
	[F9 = 3]	0.106	0.320	0.110	0.741	1.112	0.594	2.081
	[F9 = 4]	0 ^a				1		
TC ₇	[F9 = 1]	-0.350	0.370	0.891	0.345	0.705	0.341	1.457
	[F9 = 2]	0.350	0.358	0.957	0.328	1.419	0.704	2.860
	[F9 = 3]	0.230	0.340	0.457	0.499	1.258	0.646	2.449
	[F9 = 4]	0 ^a				1		
	[F10 = 1]	-1.709	0.469	13.264	0.000**	0.181	0.072	0.454
	[F10 = 2]	-1.016	0.421	5.811	0.016*	0.362	0.159	0.827
	[F10 = 3]	-1.009	0.437	5.332	0.021*	0.364	0.155	0.858
	[F10 = 4]	0 ^a				1		
TC ₂₀	[F10 = 1]	-1.135	0.398	8.148	0.004**	0.321	0.147	0.701
	[F10 = 2]	-0.614	0.379	2.623	0.105	0.541	0.257	1.138
	[F10 = 3]	-0.767	0.431	3.165	0.075	0.464	0.199	1.081
	[F10 = 4]	0 ^a				1		
TC ₁₉	[F10 = 1]	-0.625	0.398	2.469	0.116	0.535	0.246	1.167
	[F10 = 2]	0.034	0.384	0.008	0.930	1.034	0.487	2.196
	[F10 = 3]	0.185	0.432	0.183	0.669	1.203	0.516	2.804
	[F10 = 4]	0 ^a				1		
	[F11 = 1]	0.712	0.313	5.174	0.023*	2.038	1.104	3.765
	[F11 = 2]	-0.015	0.285	0.003	0.959	0.985	0.564	1.721
[F11 = 3]	0 ^a				1			

Table 10. Results of ordered logistic regression and the odds ratios

- (3) The *mandatory local policies* (F11) show a significant influence on TCs for identifying experienced partners (TC3) and signing the sale contracts (TC19). The calculation shows that with a decline of the mandatory policies from level 3 to level 1 (no mandatory policies), the odds of high TCs for identifying experienced partners will increase at 1.853 (= exp(0.617)) times. Besides, different levels of the mandatory local policies also impose a significant influence on TCs for signing the sale contracts of PH

assets. Referring to level 3, mandatory local policies on level 1 (odds ratios 2.038, CI 1.104–3.765) are more likely to incur high TCs.

- (4) The positive coefficients reveal that the developer's higher capability (F9) brings about higher TCs for procuring the general contractor (TC₁₃). The odds of the developers in group 2 cause TCs for procuring are 1.985 times higher than that of developers in group 4 (ranking lower than 100), holding all other factors constant. It implies that developers ranking at 10–50 are the ones who are bearing higher TCs for procuring the general contractor. The first group (top ten) and the third group (50–100) reveal no significant difference.

5. Findings and discussion

5.1 TCs of most concern to developers

It has been identified that the five sources of TCs of most concern in PH from the opinion of the developers in China are: Disputes (TC₁₆), Design Changes (TC₁₅), Learning (TC₅), Assembly (TC₁₇) and Decision-making (TC₆).

Developers perceive the additional costs from Disputes (TC₁₆) on a high importance level in this study. Similarly, [Lu et al. \(2015\)](#) recognized the critical influence of hidden TCs from dispute settlement in conventional projects. In China's context, developers' great concern on TCs from disputes reflected that the chance of dispute is even higher in an immature PH market. Besides, it is not surprising that Design Change (TC₁₅) got great attention from the developers. The extra workloads, regarding redesign, negotiation, the arrangement of new components production or even the new construction plan, from the design change, have been stated in previous studies ([Tam et al., 2015](#)). Another significant TCs resource is Learning (TC₅). When switching from familiar traditional production methods to those using prefabrication, practitioners noticed the additional inputs for digesting new information, mastering new technologies and collaborating with new stakeholders ([Wu et al., 2019b](#)). However, most of the time, the learning costs are kept invisible in PH because of the difficulty of measuring them at the project level. Additionally, developers believed that the Assembly (TC₁₇) is a challenging task that is incurring an added burden ([Wu et al., 2020](#)). Decision-making (TC₆) for a PH project also confronts developers with unexpected costs regarding information searching in the housing construction market, financial analysis and risk assessment ([Goodier and Gibb, 2007](#)).

If one is seeking the underlying TCs of most concern in PH, the primary sources of the top five TCs are mostly information costs. [Hobbs \(1997\)](#) defined the information costs as costs arising *ex ante* to exchange and include obtaining information on price, product and identifying suitable trading partners. The information costs stem from two aspects: *information searching* and *information exchange*. These are explained as follows:

- (1) *Information searching* and analysis are activities in Learning and Decision-making. Stakeholders are motivated to learn in a situation when there is limited or asymmetric information. As the initiator of most PH projects in China, developers are responsible for collecting and assessing information from the prefabrication market about the market size, competitors and the new prefab techniques. In this process, they invest capital, time, labor and effort to make rational decisions; and
- (2) TCs from the Design Change and Assembly are mainly linked with the *information exchange*. For example, when design changes happen, the contractor delivers the information to the architects and the developers. The resulting intensive negotiations in meetings, emails and documents will cause additional costs.

The reason developers identified TCs as being highly related to information costs can be explained by the developer's profit-driven characteristics and the hard-to-measure nature of TCs. In our survey, 72.1% of the PH projects were developed by private enterprises, naturally pursuing profits. TCs high-related to the information costs are emphasized as additional burdens because they do not directly contribute to profits. The invisibility and immeasurability of the information cost make it a focus of attention from developers.

5.2 Influencing factors and their impacts on TCs

The data analysis reveals four influencing factors of TCs: *Qualification of the general contractor* (F10), *Local mandatory policies* (F11), *Owner type* (F3) and *Competitiveness of the developer* (F9).

5.2.1 Qualification of the general contractor (F10). The *Qualification of the general contractor* (F10) is a significant explanatory parameter to four sources of TCs in PH: Dispute costs (TC₁₆); Preparing and negotiating for the financing (TC₉); Preparing and participating in the land-bidding (TC₇); and Taxation paid by the developer (TC₂₀). The survey revealed that the chosen general contractors for PH mostly have high qualifications: 30% with a special grade (highest level) and 40.1% with a first-level. In general, the higher qualification of general contractors contributes to lower TCs on these four aspects, which is in line with the argument of Li *et al.* (2014b), who believe that capable contractors could operate efficiently and contribute to a more stable environment with lower TCs. Specifically, the higher contract management ability for dispute resolution means fewer costs and time lost on negotiation, mediation, arbitration and litigation. On the other hand, as expounded by Lu *et al.* (2015), good contractors pay more attention to maintaining their reputation, which means fewer disputes by implementing sound contract management. Moreover, TCs for the financing and the land-bidding are influenced by the qualification of general contractors. The early involvement of a general contractor with strong capability will create a collaborative and supportive climate for project implementation (Wuni and Shen, 2020). It contributes to lowering the risk for financing and increasing the chance of winning the tender, thus reducing TCs.

5.2.2 Local mandatory policies (F11). As plenty of studies have emphasized the influence of policies for PH development, it is no surprise that the *Mandatory local policies* (F11) show a significant effect on two sources of TCs in this study. In PH, more precise and restrictive mandatory policies may reduce TCs for identifying experienced partners (TC₃) and signing sale contracts (TC₁₉). Particularly, when there are no mandatory policies on using prefabrication, TCs for identifying professional partners are higher than in the mandatory cases. In many of China's metropolitan cities, adopting prefabrication has become mandatory (Gan *et al.*, 2018). Consequently, enterprises in the industry have to adjust to the new market, which means there will be more candidates in the PH's supply chain to choose. This also means that there will be a shorter time for developers to search and to identify partners. Additionally, the quantitative analysis results also indicate that the stronger the promotion from the authority, the less effort is needed from the developers to sign the sale contracts. The mandatory policy is an approach of popularization of PH, by which, robust understanding and acceptance of PH among the public can be developed. Minimizing the information asymmetry between the developer and the potential buyers thus saves time on negotiation. Still, 30% of the respondents stated that there were no mandatory policies in their cities.

5.2.3 Owner type (F3). The TCs for decision-making (TC₆) can be significantly influenced by the *Owner type* (F3) of a PH project, which is consistent with a previous study by Li *et al.* (2014b). Adopting private real estate developers to develop PH projects is one of the most frequently applied ways in China for building public housing (Li *et al.*, 2014a). Developers' opinions in this study reflected that TCs for public projects are more likely to be higher than

those for private projects. For developers, public projects consume more of their efforts for deciding on adopting prefabrication, since the real client of public projects is mostly the local government, who usually holds great power in a project. It means that the pre-contract management is inefficient with less flexibility of decision for developers. In that sense, developers have to meet the real client's requirements and, at the same time, also need to have excellent communication skills to deliver the information to the contractors.

5.2.4 Competitiveness of the developer (F9). The ordered logistic regression analysis shows that developers with higher competitiveness spend higher TCs for procuring general contractors. This can be understood in practice. For example, a developer with excellent operational capacity is always prudent in selecting a general contractor, which is a measure taken beforehand to reduce the uncertainty in the contract execution stage. TCs, especially time costs, are spent on activities, such as attending meetings, preliminary design, transition observation, training and site visits to ensure the quality of the procurement (Rajeh *et al.*, 2015). Besides, rather than the low-bid principle in conventional projects, the best-value method is more reasonable when procuring contractors for PH projects. Developers with excellent sustainable development capability pursue the quality of projects rather than only the benefits. However, the efforts invested in considering the contractor's experience, reputation and ability means that they pay higher TCs and contract costs compared with merely choosing the lowest-price bidders.

There may be a number of reasons why only four of the twelve factors showed significant influences on developer-related TCs. A prominent explanation is because of the unique functions of critical stakeholders in the promotion stage of PH in China. Essentially, the four influencing factors revealed the power of the key stakeholders in PH, namely: developers, general contractors and the local governments (who decide the owner type and the level of mandatory policies). This finding is in line with other studies in the field of PH, which affirms the remarkable role of these three key stakeholders in the developing stage in promoting PH (Wu *et al.*, 2019b). The roles of the developers and contractors were also shown to have substantial influences on TCs, compared to their conventional counterparts (Li *et al.*, 2012). Additionally, regarding the original principal of TCs economic theory, Williamson (1985) had claimed the fundamental determining effects of actors in the transactions.

5.3 Recommendations for minimizing the developer-related TCs

5.3.1 Recommendation for the developers. In a PH project, not all the identified influencing factors are amenable to change by the developers. Developers in China's PH industry are suggested to take measures according to the critical TCs and the factors that they can decide or influence in PH – Qualification of the general contractor and the Competitiveness of the developer.

- (1) Reducing costs from *information searching*: For the developers, learning activities (e.g. in the form of meetings, project investigations) are encouraged to minimize the TCs from the mistakes and low efficiency in the assembly stage (Kiss, 2016). Besides, from real estate company management, experiential learning can save time on Decision-Making (Coggan *et al.*, 2013).
- (2) Reducing costs from *information exchange*: Having a complete design scheme helps to decrease the TCs from information exchange by reducing the subsequent number of Design Changes and Disputes in PH projects. A well-defined project scope and technical illustration reduce the uncertainties in the subsequent transactions, hence lowering the TCs (Li *et al.*, 2015). The potential difficult issues in the manufacture, the components transportation and the assembly onsite can be identified and solved in the design stage (Zhang and Yu, 2020).

- (3) Even though the data analysis showed that the higher competitiveness of the developer related to higher TCs for procuring the general contractor, it is not reasonable that the developers should keep their competitiveness at a low level; On the contrary, improving the capability of the developer is always a rational option to reduce the TCs for the development process, although it may result in higher TCs in some of the tasks. The enhancement of developers' competitiveness can be achieved in many aspects; for instance, building good relationships with other parties to improve the predictability of their behavior (Li *et al.*, 2012). A practical aspect for developers to enhance their competitiveness is to update the firm's organizations to adapt to the prefabrication production mode. A high institutional efficiency allows a smooth operation, and a more stable environment, reducing TCs.
- (4) Another influencing factor that can be decided by the developers is the qualification of the general contractor. Our findings conclude that a general contractor with a high qualification contributes to reducing TCs arising from Disputes, Financing, Land-bidding and Taxation. As Li *et al.* (2014b) stated, contractors with high capabilities would efficiently contribute to the operation and promote a problem-free environment, contributing to a more stable environment with lower TCs. A rational developer should choose the highly-qualified general contractors, as long as the budget allows.

5.3.2 Recommendation for the policy-makers. This study has presented the critical influence of mandatory local policies on the transaction efficiency of PH projects. This is in line with the argument of Gao and Tian (2020), who stated that the supportive industrial policies by Chinese local governments to promote PH are necessary and effective. From the perspective of the TCs theory, governments' interventions to secure a favorable transaction environment are essential in an innovation industry like PH (Qian *et al.*, 2013). According to our study results, and considering the actual situation of PH in China, some policy implications are recommended for Chinese local authorities:

- (1) To popularize the mandatory local policies in Chinese provinces. The mandatory policy is a practical approach for educating stakeholders, by which the uncertainties on the aspects of the technique can be vastly reduced, contributing to the minimization of TCs. However, there were still 30% of the respondents who stated that there were no mandatory policies in their regions. A recent study by Gao and Tian (2020) also indicated that only 10/34 provinces in China have supportive regulations for PH. It is, therefore, necessary to enforce the implementation of a mandatory generalised policy for PH in Chinese provinces.
- (2) The mandatory policy needs to suit the PH level of the local market. Lu *et al.* (2018) argued that the optimal level of prefabrication is produced by bounded-up forces from the aspects of political, economic, social and technological. Although the findings from this study indicated that a higher level of the mandatory policy contributes to reducing TCs, the target prefabrication rate should be set considering the practical situation of the applied region. For example, in the primary promotion region, particular requirements on the prefab rate can be set for projects that apply prefabrication. Simultaneously, the focus of mandatory policies in the encouraged promotion region should focus on qualifying the quality of PH projects instead of only pursuing a high prefabrication rate. It is necessary for the local governments to formulate mandatory punitive regulations for ensuring the quality of PH projects.
- (3) The mandatory local policy should be specific, with detailed implementation measures. Greenstone and Hanna (2014) stated that policies and action plans with

detailed measures are more effective in their study of India's environmental regulation. The Chinese central government has issued a series of national technical standards that can meet the needs of current mainstream PH projects (Luo *et al.*, 2020). However, the effectiveness of the issued national standards is constrained because of the lack of local supportive regulations in terms of the training, education or skill certification of construction workers. TCs from learning can be effectively reduced when the economic scale of PH be attained with the support of systemic education and certification regulation by the local governments.

6. Conclusions

Under the conditions that TCs are bringing additional burdens to the private stakeholders in PH, this study explored the factors influencing TCs in China's market from the developers' perspective. The statistical analysis showed that the developers perceived *Disputes* as the most critical source of TCs in PH in China's PH market. *Design changes*, *Learning*, *Assembly* and *Decision-making* are also identified as relevant sources of TCs. Besides, the correlation analyses and ordered logistic regression indicated that the most influential factors for developer-related TCs in PH projects are: *Qualification of the general contractor*, *Local mandatory policies*, *Owner type* and *Competitiveness of the developer*.

In line with similar arguments from the conventional construction management and the TCs economic theory, this result highlights stakeholders' determining effects on TCs in the PH field. The ordered logistic regression also explained the directions of impacts from the influencing factors to particular TCs. The higher Qualification of a general contractor contributes to lowering the TCs for Dispute, Financing, Land-bidding and Taxation. Improving the level of mandatory policies can reduce TCs arising from Identifying experienced partners and Signing sale contracts. Moreover, for the developers, TCs for decision-making in public projects are more likely to be higher than in private projects. Additionally, it was unexpected to find that the developer's more potent capability related to even higher TCs for procuring the general contractor, a finding which is counter-intuitive.

The results of critical TCs and influencing factors have provided substantial evidence on the mechanism of TCs in PH, which, in turn, inspires their application to minimize TCs for developers. Thus, there are three aspects to consider in these results:

First, in order to understand the essence of the identified critical TCs, corresponding measures are suggested to reduce developer TCs of most concern from the aspects of information searching and exchange. The activities of learning, such as project visits, educating and meetings, are encouraged in order to reduce those high TCs arising from information searching in the subsequent tasks of Assembly and Decision-Making. Besides, developers are suggested to ensure the completeness of the design, in order to decrease the risks from subsequent Design Changes and Disputes, thus saving potential hidden costs from information exchange.

Second, suggestions are given to the developers regarding the influencing factors and the influencing mechanism. It is proposed that developers reduce TCs by enhancing their competitiveness, building good relationships with other parties and upscaling the organization to improve their institution's efficiency. Moreover, developers are recommended to procure general contractors with high qualifications as long as their budget allows.

Third, policy recommendations are provided for the local governments to reduce TCs. The mandatory policies are expected to be popularized in Chinese provinces, while the level of the mandatory policies should be set considering the practical situation of different regions. TCs from learning can be effectively reduced when the economic scale of PH be obtained with the support of building systemic education and certification regulation by the local governments.

The contribution of this paper is to extend the theory by exploring factors that influence TCs in the PH and shedding light on the influencing mechanism of TCs. Practically, this study helps the developers investigate the nature of their TCs of most concern and further analyze the underlying reasons. Providing the enterprises understand how the influences are imposed, suggestions for developers are on the practical level to benefit the controlling of TCs in PH projects. Using a focus on the TCs of developers, the findings and methods in this study can be further applied to analyze the TCs of other PH stakeholders. Furthermore, taking China's market as an example, the conclusions of this study also provide useful references to PH in other developing countries and transitional construction markets.

There are some limitations to this study. One of them is that, when validating the list of the factors, an important factor – “social climate and attitude” – was suggested to be removed due to the difficulty of quantifying it in the model. Another limitation of this study is that the results are based on the market conditions current at the time of the survey, which may not be used to explain TCs and their influencing factors when the maturity of the PH industry is different. Therefore, the factors could be adjusted according to actual conditions when applied to other countries or to different PH development periods.

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